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PERFORMANCE OF THE SOMERSET OXIDATION DITCH

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Ohio University,
Athens, Ohio

1969

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Introduction

The oxidation ditch plant at Somerset, Ohio was studied for three years, June 1966 to May 1969, supported by a demonstration grant from the Federal Water Pollution Control Administration. Objectives of the project were (1) to determine design criteria for oxidation ditches, based upon an evaluation of a full-scale plant and (2) to determine desirable operational procedures for optimum performance of these treatment units. To accomplish these objectives, systems analysis techniques were to be employed as the tool.

Systems analysis is a method of studying complex inter-relationship problems of design selection or evaluation. In this approach, decision-making is performed even though some conditions pertaining to the operating system are not known with a high degree of certainty. It tries to designate each element of an operating system complex in its proper context, so that the system as an integrated whole will attain the desired objectives with a minimum expenditure of resources.

Although the development of the appropriate systems analysis techniques constituted a considerable part of the effort on this project, it will not be discussed in this presentation. This report will discuss the operational performance of the Somerset plant in a more traditional and familiar manner. Results to be presented include velocity measurements, plant performance as reflected by suspended solids and biochemical oxygen demand (BOD) removals, and other items

such as mixed liquor suspended solids, sludge drying, and power consumption.

Description of the Plant

The Somerset plant consists of two concrete-lined oxidation ditches, each having a volume of 208,000 gallons. At present only one ditch is needed to serve the community. Each ditch has two cage rotor aerators, each 27 1/2 inches in diameter and 8 feet long. As Figure 1 shows, two final settling tanks follow the ditches. Sludge is returned to the ditch by air lift. Waste sludge goes to sand drying beds. Not shown on the sketch are two pumps, each having a capacity of 300 gpm, which lift the raw wastewater to the comminutor.

The plant was designed by Underwood Engineering of Somerset, Ohio. The aerator rotors were supplied by Lakeside Engineering of Chicago.

Velocity Measurements

Velocity measurements were taken across a section about midway along the straight portion of the ditch track, 66 ft downstream from an aerator rotor. Figures 2, 3, and 4 show the velocity distributions rotor immersions of 4, 6, and 9 inches, respectively. Each plotted value is the ratio of the velocity at that point to the average velocity for the entire cross-section. Selected contour lines have been drawn connecting points of equal ratio values.

The average velocity increases from 1.55 ft per sec (fps) at 4 in. immersion to 1.65 fps at 6 in immersion to 1.92 fps at 9 in immersion. The velocities are distributed so that the higher values are near the water surface and slightly off center towards the outer side of the ditch cross-section. Figure 5 shows that the high velocity core

shifts even more towards the outer side at the bend in ditch track.

Plant Performance

a. Sampling

Samples were collected one to three times per week. Automatic samplers were used whenever possible. A Phipps and Bird 8392 dipper-type sampler was used to collect raw wastewater. A Brailsford Model DU-1 sampler was used to collect final effluent. The sampling periods varied from about 8 to 24 hours. When the automatic samplers were inoperative, samples were collected manually every hour or two and composited over a 6- to 8-hour period. Samples were refrigerated during collection.

Laboratory analyses were carried out according to Standard Methods for the Examination of Water and Wastewater, 12th edition, 1965.

b. Average Results

In Figure 6, the monthly average concentrations of suspended solids and BOD show that the plant achieves overall excellent removals of these two major constituents of wastewater. The singularly poor removal of both in January 1968 will be discussed in detail later.

Table 1 shows the same information contained in Figure 6 and in addition the monthly average flow and BOD loading data. The design BOD loading criterion used for this plant was 12.5 lb per day per 1000 cu ft of ditch volume. Thus the plant has been operating at about half the design load much of the time. The overall average values at the bottom of the table confirm this conclusion.

Average power consumption for all uses at the plant was as follows:

1966-67	3010 kwh/10^6 gal	1.74 kwh/lb BOD removed
1967-68	3550 "	1.83 "
1968-69	4720 "	2.32 "

c. Heaviest BOD Loadings

Although the plant was usually underloaded, occasional loadings well in excess of the design value were encountered. Table 2 shows an array in decreasing order of magnitude of the highest BOD loadings and the corresponding quality of the final effluent. With one exception, all the flows were higher than normal.

As Loadings 2 and 3 suggest, excellent BOD removals can be attained even with about a 40 percent overload, if the detention time in the ditch is not less than about 18 hours and the flow does not occur in surges. In both of these instances, the contributions from rain seem to have been evenly distributed so that surges did not occur. Flow surges seemed to flush out activated sludge to cause high effluent BOD concentrations in Loadings 6 and 9.

The poor BOD removals in Loadings 8, 13, and 16 were caused by mechanical troubles. In 8 and 16, the aerator rotors stopped running during the night and were not re-started until the operator came on duty in the morning. In 13, a plastic sheet fouled the air lift for the return sludge and thus with the removal of settled sludge impaired, gas bubbles of denitrification probably floated some sludge over the final tank weirs.

For Loading 6, the results for the following day are shown to illustrate how quickly the plant can recover.

d. Highest Effluent BOD

The ten highest BOD concentrations found in the final effluent

are shown in Table 3. Assuming that an occasional concentration of 30 mg/l is acceptable, this plant seems to be working well.

As the table indicates, the eight highest effluent BOD concentrations were paired with extremely high suspended solids concentrations.

e. Worst Month

The obviously worst month from the standpoint of BOD and suspended solids removals was January 1968, as was indicated earlier in Figure 6. Table 4 shows additional details for this month. Rain was recorded only during the last four days of the month.

The two highest effluent BOD and suspended solids concentrations for the three-year study period were found on the 11th and 22nd of this month.

The week preceding the 11th was rather cold with the temperature averaging around 15°F. With the cold weather accompanying rather low flows during this period, ice formed on the surface of the final tanks and impaired settling. The subsequent loss of sludge affected the mixed liquor suspended solids concentration. Thus with a low concentration of biological material and the cold temperature retarding biological activity, plant performance suffered. The retarded biological activity is also reflected in the accumulation of ammonia and nitrites in the final effluent.

A satisfactory explanation for the poor performance on the 22nd has not been found. Perhaps the sudden warming trend caused a transient condition affecting the biological balance in the treatment process.

f. Mixed Liquor Suspended Solids

Figure 7 is a comparison of the trends of the percent volatile suspended solids and the total suspended solids in the mixed liquor. The two trends go in opposite directions--as one increases, the other decreases. This suggests that the inert, or fixed, portion of the mixed liquor suspended solids is affected more than the organic portion as the quantity of solids changes.

g. Sludge Drying

The drying rate of the waste sludge placed on the sand beds was recorded sporadically during the three-year period. The few observations that were recorded indicate that the sludge was dry enough for removal from 5 to 20 days after application on the sand bed during the summer and early fall. Depths of the freshly applied sludge varied from about 6 to 12 in. During the summer, 5 or 6 days were sufficient when rain did not hinder the drying process. The longer drying times were invariably associated with appreciable rainfalls. For example, for one batch that required 18 days to dry, rainfalls of 0.2, 0.3, 0.4, and 0.5 in occurred on the 4th, 7th, 8th, and 15th days. For another batch that required 19 days to dry, 3.1 of rain fell between the 3rd and 13th days of the drying period.

Summary

A three-year study has shown that the oxidation ditch is a dependable and effective treatment unit for domestic wastewater. As in any activated sludge type of treatment unit, it is affected greatly by flow surges. Power consumption, the largest item of operational cost, seems to compare favorably with other extended-aeration processes.

Acknowledgment

This project was supported in part by a Water Supply and Pollution Control Demonstration Grant No. WPD 100-01(R1)66, WPD 100-02-67, and WPD 100-03-68 from the Division of Research and Training Grants, Federal Water Pollution Control Administration.

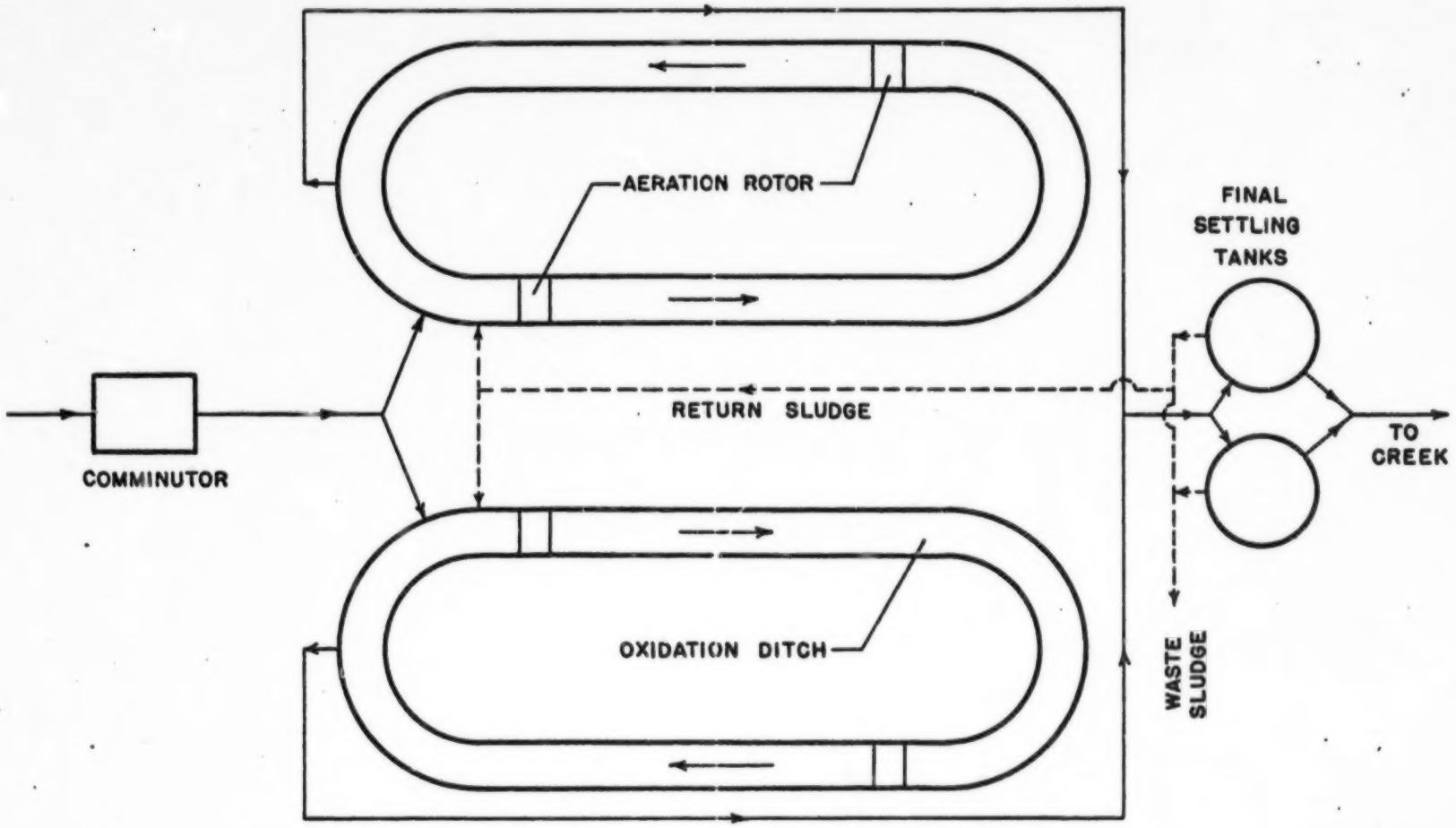


Figure 1
SCHEMATIC DIAGRAM OF OXIDATION DITCH PLANT
AT SOMERSET, OHIO

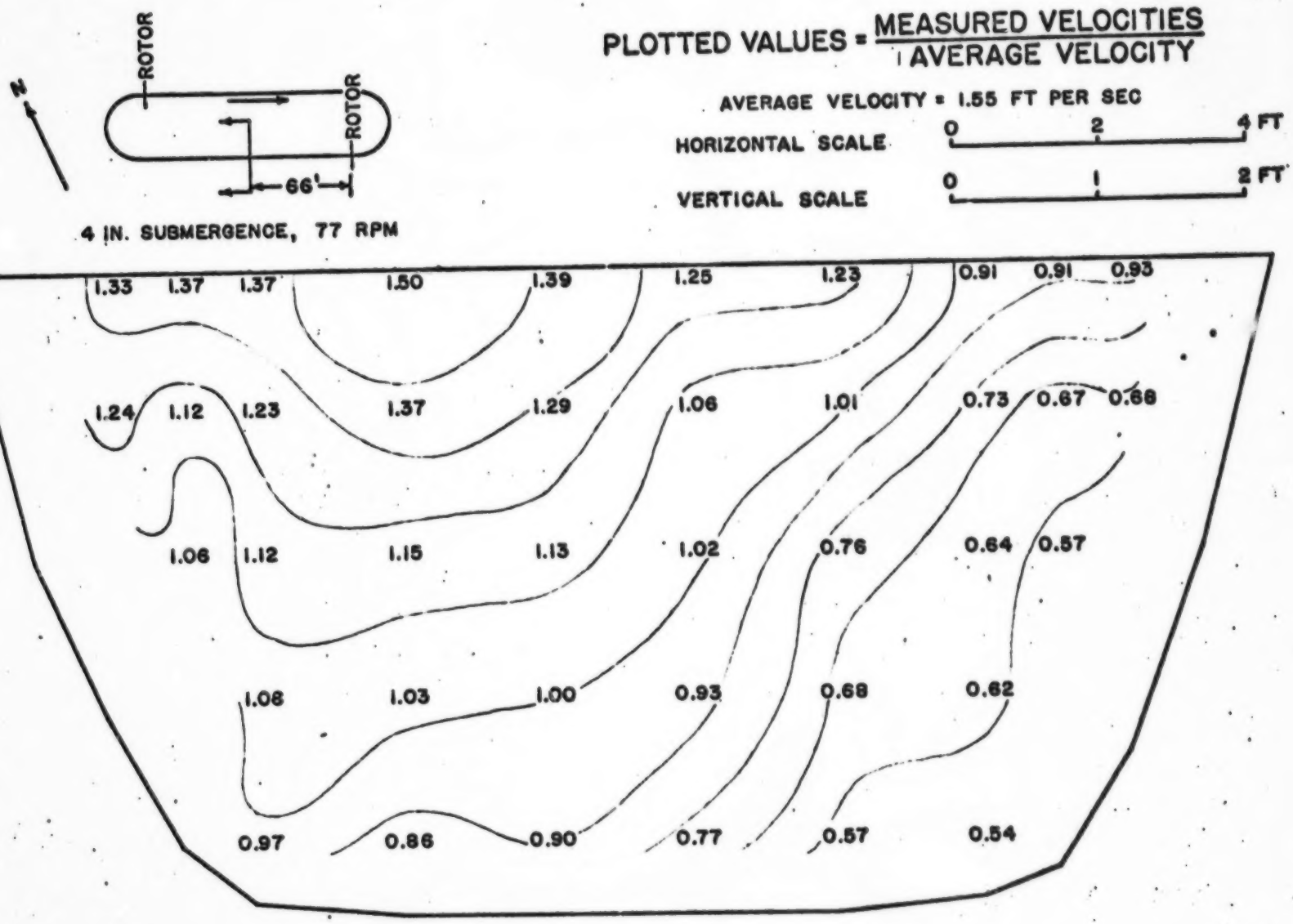
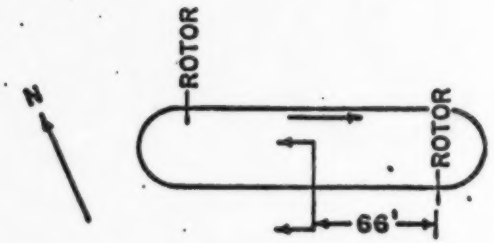


Figure 2

VELOCITY DISTRIBUTION IN OXIDATION DITCH SECTION

9/22/68



6 IN. SUBMERGENCE, 77 RPM

PLOTTED VALUES = MEASURED VELOCITIES / AVERAGE VELOCITY

AVERAGE VELOCITY = 1.65 FT PER SEC

HORIZONTAL SCALE 0 2 4 FT

VERTICAL SCALE 0 1 2 FT

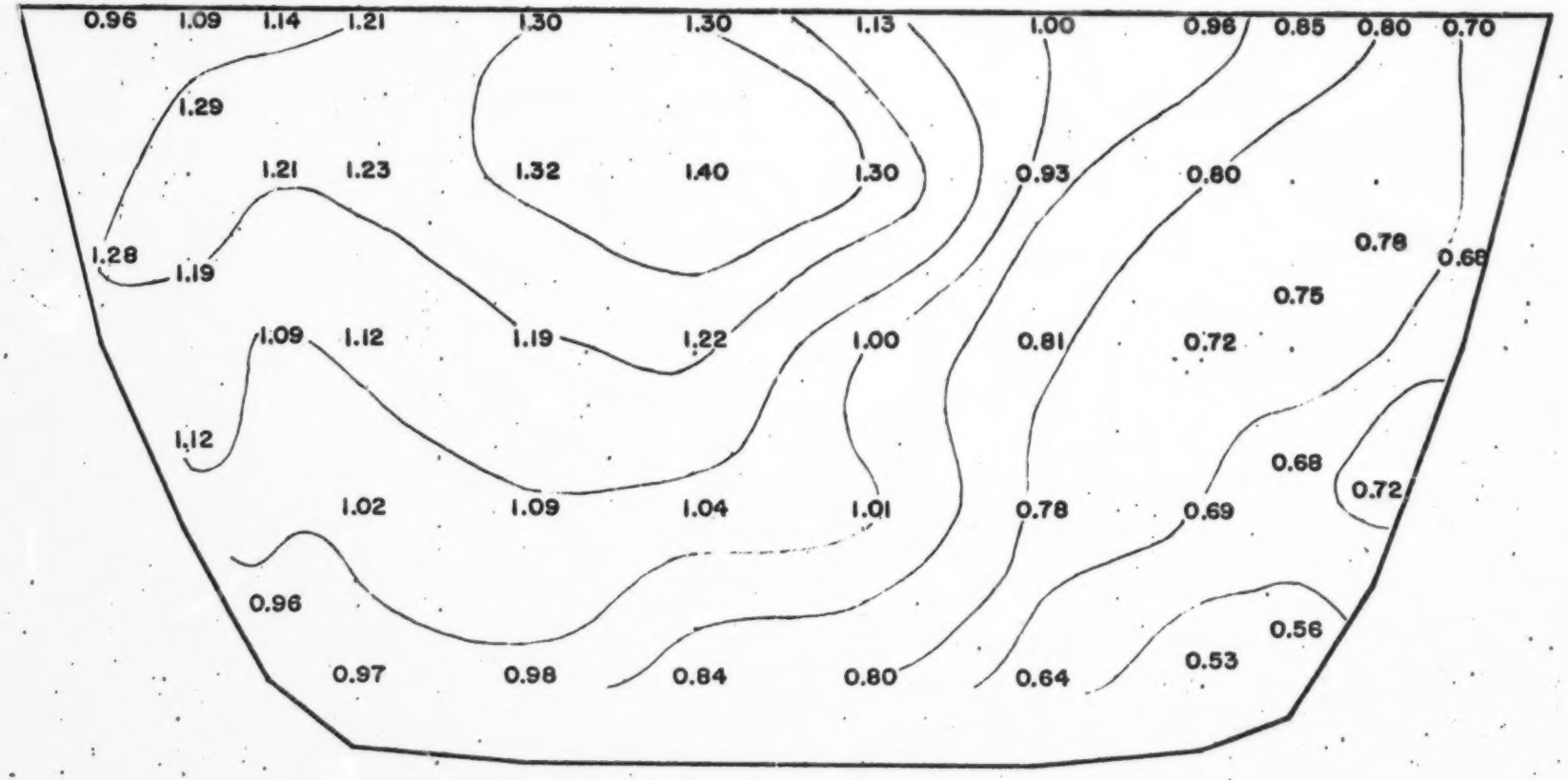


Figure 3

VELOCITY DISTRIBUTION IN OXIDATION DITCH SECTION

7/18/67

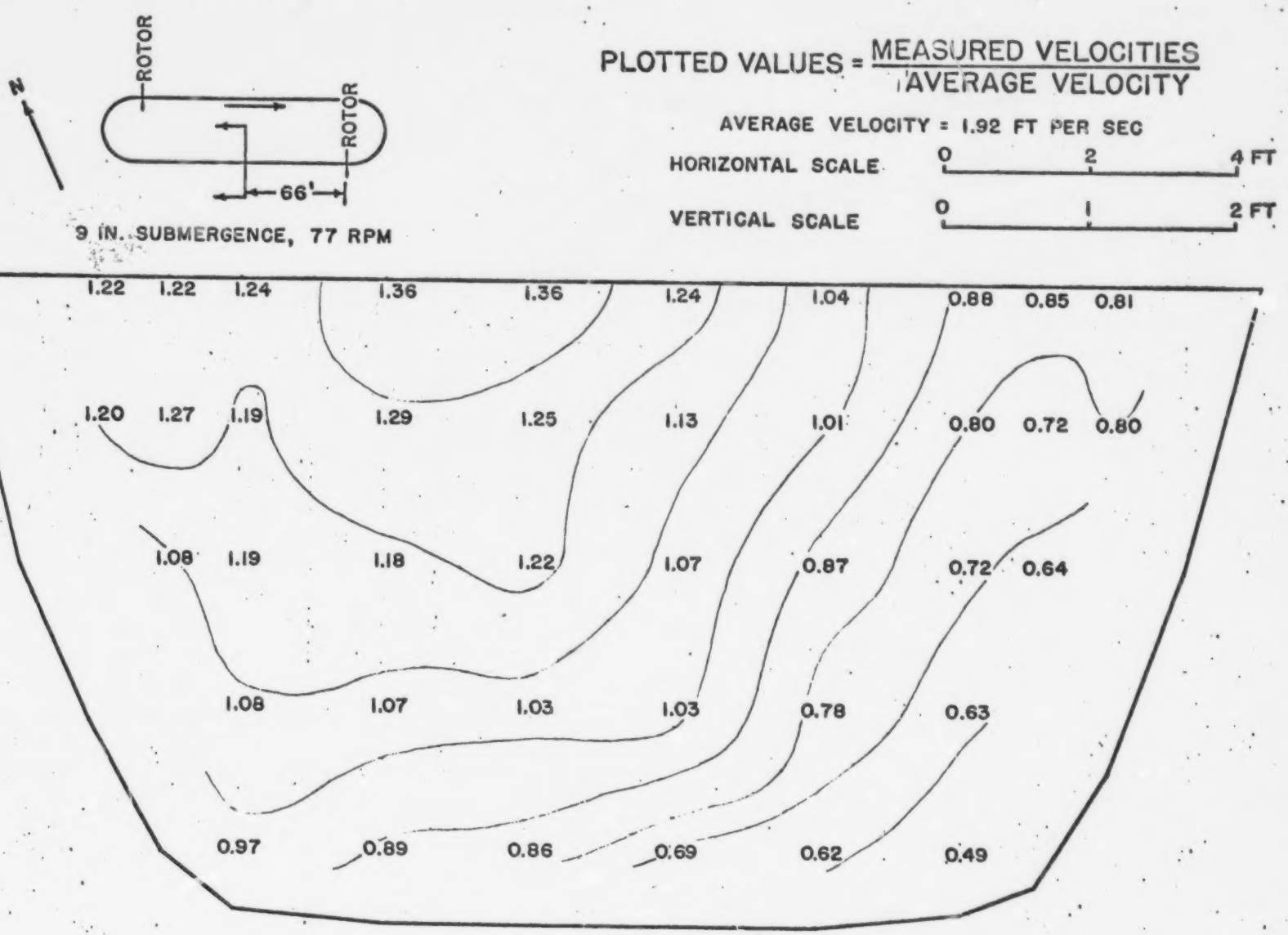


Figure 4

VELOCITY DISTRIBUTION IN OXIDATION DITCH SECTION

9/23/

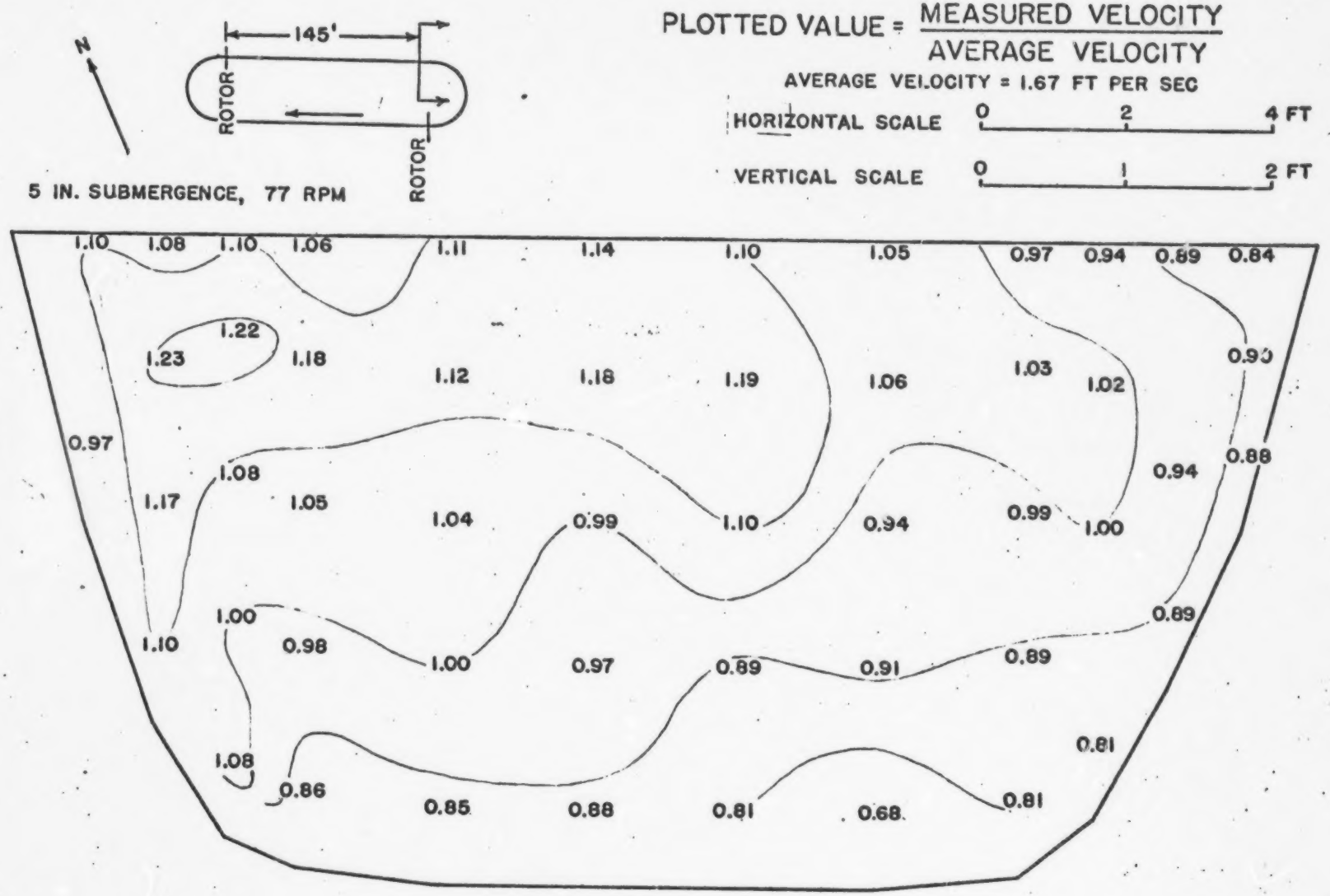


Figure 5

VELOCITY DISTRIBUTION IN OXIDATION DITCH SECTION

8/23/66

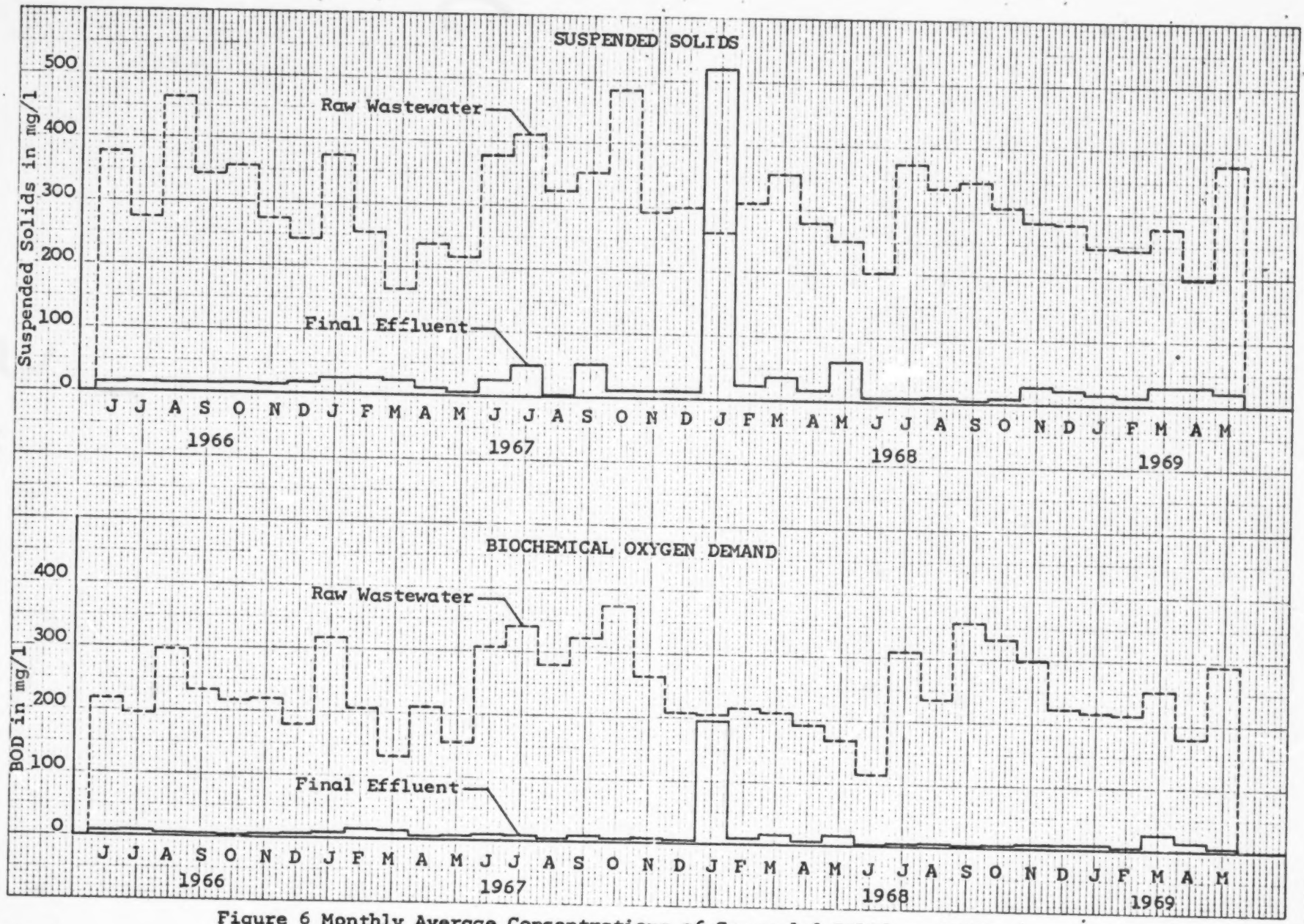


Figure 6 Monthly Average Concentrations of Suspended Solids and BOD

30 Squares to the Inch

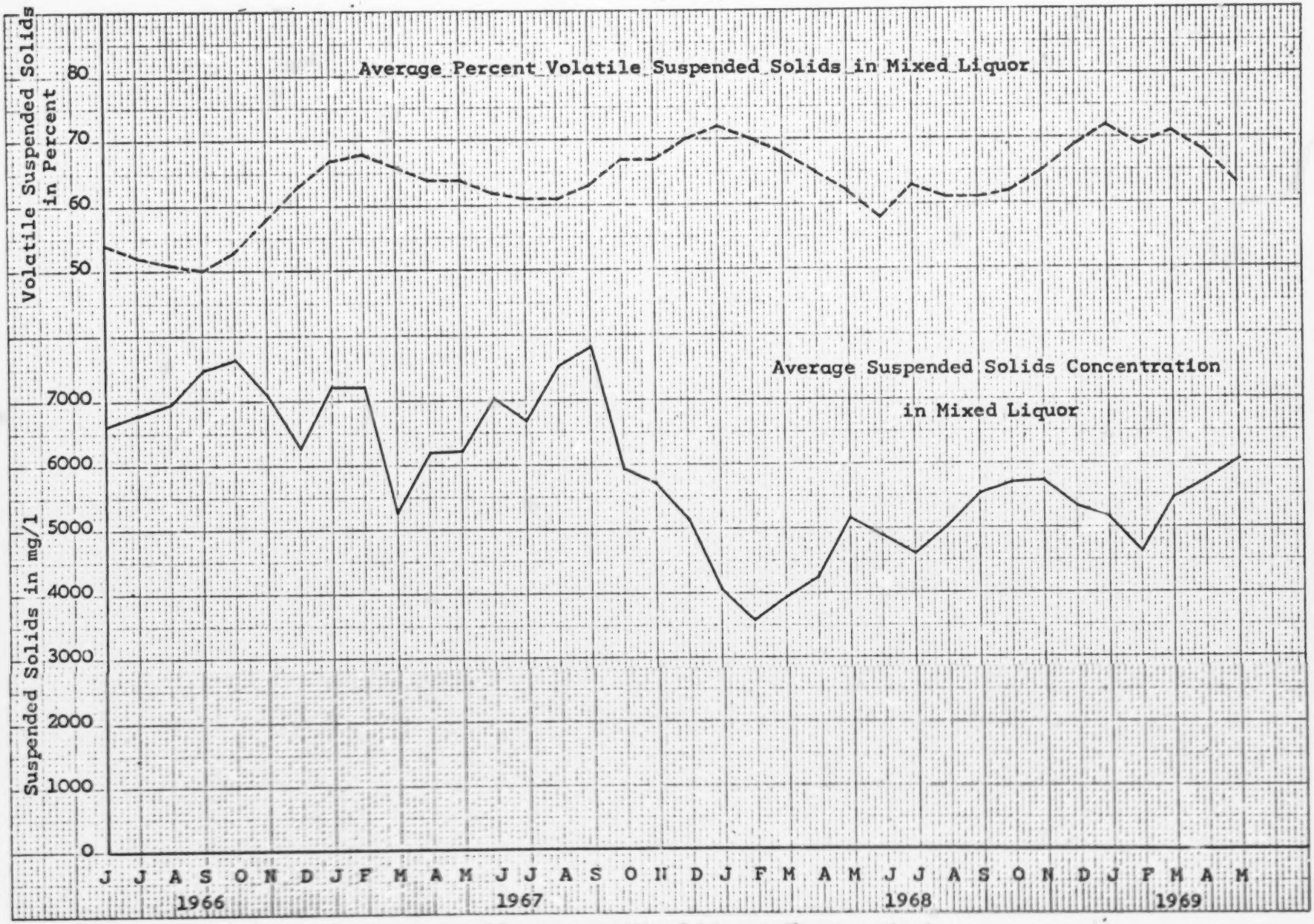


Figure 7 Monthly Average Mixed Liquor Characteristics

20 Squares to the Inch

Table 1 Monthly Averages

MONTH	FLOW gpd	SUSPENDED SOLIDS mg/l RAW	SUSPENDED SOLIDS mg/l FINAL	BOD mg/l RAW	BOD mg/l FINAL	BOD LOADING lb/day/1000 cu ft
June 1966	52,000	377	13	218	7	3.4
Jul	97,000	275	15	196	8	5.7
Aug	54,000	464	13	295	4	4.8
Sep	63,000	343	14	232	3	4.4
Oct	51,000	357	15	216	3	3.3
Nov	100,000	275	13	220	5	6.6
Dec	172,000	243	18	180	5	9.3
Jan 1967	87,000	376	24	318	9	8.3
Feb	132,000	253	25	206	14	8.2
Mar	337,000	165	23	131	14	13.2
Apr	125,000	237	11	210	5	7.9
May	192,000	217	5	155	8	8.9
Jun	66,000	379	25	307	10	6.1
Jul	57,000	412	49	341	9	5.8
Aug	46,000	323	3	281	4	3.9
Sep	48,000	352	51	323	10	4.6
Oct	55,000	485	12	376	6	6.2
Nov	64,000	292	11	263	7	5.0
Dec	104,000	301	11	208	6	6.5
Jan 1968	144,000	262	520	206	196	8.9
Feb	149,000	310	22	216	10	9.7
Mar	195,000	354	37	210	17	12.3
Apr	87,000	280	17	191	7	5.0
May	247,000	251	62	169	17	12.5
Jun	151,000	201	7	114	2	5.2
Jul	56,000	374	7	310	4	5.2
Aug	81,000	337	9	235	6	5.7
Sep	63,000	347	4	357	4	6.8
Oct	58,000	308	9	331	5	5.8
Nov	56,000	285	28	298	8	5.0
Dec	86,000	283	21	222	8	5.7
Jan 1969	106,000	246	17	218	9	6.9
Feb	143,000	243	13	216	6	9.3
Mar	88,000	278	30	252	27	6.6
Apr	114,000	199	30	180	13	6.2
May	75,000	378	22	292	6	6.6
1966-67 Ave.	122,000	298	16	215	7	7.0
1967-68 Ave.	105,000	333	68	258	25	7.2
1968-69 Ave.	90,000	290	16	252	8	6.2
3-Year Ave.	106,000	307	34	241	13	6.8

Table 2 BOD Removals at Heavy Loadings

(Design Loading = 12.5 lb/day/1000 cu ft)

LOADING MAGNITUDE	DATE	RAW WASTEWATER BOD lb/day per 1000 cu ft	RAW WASTEWATER BOD mg/l	FINAL BOD mg/l	FLOW gpd
1	29 Jan 68	27.0	108	21	834,000
2	21 Apr 67	18.3	328	5	186,000
3	20 Sep 66	17.1	201	4	284,000
4	21 Mar 68	16.1	77	16	696,000
5	13 Mar 67	15.8	122	13	433,000
6	27 Sep 67	15.0	318	76	137,000
	(28 Sep 67	5.5	225	5	82,000)
7	31 Jan 68	14.0	100	16	467,000
8	18 Jul 67	13.5	310	11	145,000
9	7 Aug 68	13.2	231	21	190,000
10	31 Jan 67	12.1	283	8	142,000
11	11 Dec 67	12.0	178	8	225,000
12	24 Mar 67	12.0	147	8	271,000
13	26 Jul 67	11.4	396	38	96,000
14	19 May 67	11.4	118	8	322,000
15	12 May 67	11.0	146	7	252,000
16	17 Mar 67	10.6	132	30	267,000

Table 3 Highest BOD Concentration in Final Effluent and Associated Data

		FINAL EFFLUENT				RAW WASTEWATER	
ORDER	DATE	BOD mg/l	SUSPENDED SOLIDS mg/l	AMONG 10 HIGHEST SUSP. SOL.	FLOW gpd	BOD mg/l	SUSPENDED SOLIDS mg/l
1	11 Jan 68	701	1880	X	57,000	287	355
2	22 Jan 68	430	1184	X	170,000	164	191
3	27 May 68	109	396	X	666,000	26	79
4	17 Mar 69	95+	84	X	67,000	329	393
5	19 Mar 69	82+	72	X	63,000	305	255
6	27 Sep 67	76	532	X	157,000	318	360
7	7 Apr 69	59	121	X	169,000	120	169
8	26 Jul 67	38	374	X	96,000	396	444
9	17 Mar 67	30	32		267,000	132	156
10	13 Mar 68	30	36		61,000	435	642

Table 4 Poorest Month of Three-Year Period
(January 1968)

Date	Flow	Mixed Liquor Susp. Solids	Ave. Air Temp.	Sample	Susp. Solids	BOD	NH_3-N	NO_2-N	NO_3-N
	gpd	mg/l	°F		mg/l	mg/l	mg/l	mg/l	mg/l
3 Jan	67,000	5740	22	Raw	286	264	23	0.1	0
				Final	8	5	1.3	0.1	35
8 Jan	51,000	4890	15	Raw	495	314	32	0	0
				Final	11	5	12	0.3	27
11 Jan	57,000	3340	19	Raw	355	287	28	0	0
				Final	1880	701	16	2.0	16
22 Jan	170,000	4150	40	Raw	191	164	14	0	0
				Final	1184	430	4.8	1.1	15
29 Jan	834,000	2200	46	Raw	122	108	10	0.3	2.7
				Final	18	21	1.9	1.5	10
31 Jan	467,000	2590	41	Raw	125	100	10	0.3	5.7
				Final	16	16	0.6	0.9	14